Requested Patent: WO9318541A1

Title: METAL IODIDE LAMP ;

Abstracted Patent: WO9318541 ;

Publication Date: 1993-09-16 ;

Inventor(s):

FEURSANGER ALFRED E (US); STRUCK CHARLES WILLIAM (US); KEEFFE WILLIAM M (US); SHEA MICHAEL J (US) ;

Applicant(s): FLOWIL INT LIGHTING (NL) ;

Application Number: WO1993NL00049 19930303 ;

Priority Number(s): US19920845285 19920303 ;

IPC Classification: H01J61/12 ;

Equivalents:

CA2090360, DE69327275D, DE69327275T, EP0582709 (WO9318541), B1


ABSTRACT:

A discharge lamp has a chemical fill in the discharge tube comprising an inert starting gas, mercury, alkali metal iodides, and a sufficient amount of scandium iodide and at least one iodide of a rare earth to increase the concentration of the rare earth in the vapor during lamp operation so as to enhance the color rendering index of the lamp to a value greater than about 80 and result in a color temperature between about 3000 to about 5000 degrees Kelvin.

**PCT** WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H01J 61/12

A1

(11) International Publication Number: WO 93/18541

(43) International Publication Date: 16 September 1993 (16.09.93)

(21) International Application Number: PCT/NL93/00049

(22) International Filing Date: 3 March 1993 (03.03.93)

(30) Priority data:
07/845,285 3 March 1992 (03.03.92) US

(71) Applicant (*for all designated States except US*): FLOWIL INTERNATIONAL LIGHTING (HOLDING) B.V. [NL/NL]; "Atrium" Building, 2nd Floor, Strawinskylaan 3037, NL-1077 ZX Amsterdam (NL).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*) : FEURSANGER, Alfred, E. [US/US]; 66 Overlook Drive, Framingham, MA 01701 (US). STRUCK, Charles, William [US/US]; 22 Cheney Pond Road, Medfield, MA 02052 (US). KEEFFE, William, M. [US/US]; 18 Haven Avenue, Rockport, MA 01966 (US). SHEA, Michael, J. [US/US]; 11 Church St., Apt. 320, Salem, MA 01970 (US).

(74) Agent: DE HOOP, Eric; Octrooibureau Vriesendorp & Gaade, P.O. Box 266, NL-2501 AW The Hague (NL).

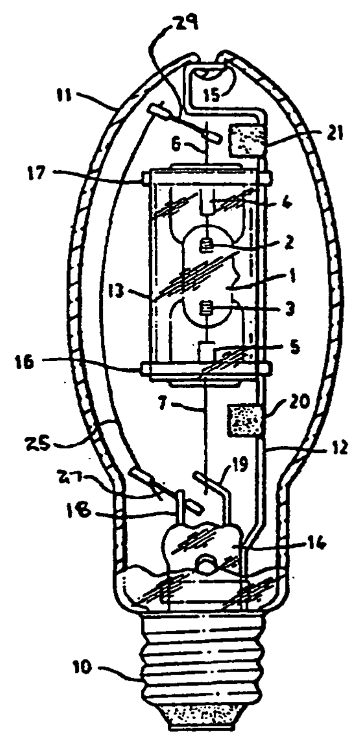
(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).

**Published**
*With international search report.*
*Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

(54) Title: METAL IODIDE LAMP

(57) Abstract

A discharge lamp has a chemical fill in the discharge tube comprising an inert starting gas, mercury, alkali metal iodides, and a sufficient amount of scandium iodide and at least one iodide of a rare earth to increase the concentration of the rare earth in the vapor during lamp operation so as to enhance the color rendering index of the lamp to a value greater than about 80 and result in a color temperature between about 3000 to about 5000 degrees Kelvin.



*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | | | | | |
|---|---|---|---|---|---|
| AT | Austria | FR | France | MR | Mauritania |
| AU | Australia | GA | Gabon | MW | Malawi |
| BB | Barbados | GB | United Kingdom | NL | Netherlands |
| BE | Belgium | GN | Guinea | NO | Norway |
| BF | Burkina Faso | GR | Greece | NZ | New Zealand |
| BG | Bulgaria | HU | Hungary | PL | Poland |
| BJ | Benin | IE | Ireland | PT | Portugal |
| BR | Brazil | IT | Italy | RO | Romania |
| CA | Canada | JP | Japan | RU | Russian Federation |
| CF | Central African Republic | KP | Democratic People's Republic of Korea | SD | Sudan |
| CG | Congo | | | SE | Sweden |
| CH | Switzerland | KR | Republic of Korea | SK | Slovak Republic |
| CI | Côte d'Ivoire | KZ | Kazakhstan | SN | Senegal |
| CM | Cameroon | LI | Liechtenstein | SU | Soviet Union |
| CS | Czechoslovakia | LK | Sri Lanka | TD | Chad |
| CZ | Czech Republic | LU | Luxembourg | TG | Togo |
| DE | Germany | MC | Monaco | UA | Ukraine |
| DK | Denmark | MG | Madagascar | US | United States of America |
| ES | Spain | ML | Mali | VN | Viet Nam |
| FI | Finland | MN | Mongolia | | |

# METAL IODIDE LAMP

## TECHNICAL FIELD OF THE INVENTION

This invention relates to metal iodide lamps, and more particularly to metal iodide high intensity discharge (HID) lamps having improved color rendering.

## BACKGROUND OF THE INVENTION

Metal halide lamps have an inner quartz arc tube containing a fill and are surrounded by an outer glass envelope. The metal halide lamp's arc tube fill includes a rare gas for starting, a quantity of mercury to establish the arc at the desired power level, and one or more metal halides, usually iodides. These metal halides are responsible for a much higher luminous efficacy and color rendering index for the lamp output than is possible for the mercury vapor lamp.

Certain terms as used in this specification have meanings which are generally accepted in the lighting industry. These terms are described in the IES LIGHTING HANDBOOK, Reference Volume, 1984, Illuminating Engineering Society of North America. The color rendering index of light source (CRI) is a measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a reference source of comparable color temperature. The CRI rating consists of a General Index, $R_a$, based on a set of eight test-color samples that have been found adequate to cover the color gamut. The color appearance of a lamp is described by its chromaticity coordinates which can be calculated from the spectral power

distribution according to standard methods. See CIE, Method of measuring and specifying colour rendering properties of light sources (2nd ed.), Publ. CIE No. 13.2 (TC-3,2), Bureau Central de la CIE, Paris, 1974. The CIE standard chromaticity diagram includes the color points of black body radiators at various temperatures. The locus of blackbody chomaticities on the x,y-diagram is known as the Planckian locus. Any emitting source represented by a point on this locus may be specified by a color temperature. A point near but not on this Planckian locus has a correlated color temperature (CCT) because lines can be drawn from such points to intersect the Planckian locus at this color temperature such that all points look to the average human eye as having nearly the same color. Luminous efficacy of a source of light is the quotient of the total luminous flux emitted by the total lamp power input as expressed in lumens per watt (LPW or lm/W).

The luminous efficacy, color rendering index and other lamp output characteristics may be varied, depending upon the particular composition of the metal halides in the arc tube. GTE's Metalarc M100/U lamp, with a $NaIScI_3CsI$ chemistry, has a color rendering index (CRI) of 65, an initial lumens per watt (LPW) of 85, and a 10,000 hour lifetime. In the lighting industry, these specifications are considered very good for standard lighting applications. Each chemical in the lamp fill is chosen to contribute specific effects to the lamp's performance. The alkali metal halides improve the color quality, contribute to lumen output of the lamp through strong emissions, and adjust the current-voltage characteristics. Scandium is added to the lamp as an iodide and as a pure metal. Scandium iodide improves color quality by adding a multitude of lines to the emission spectrum. The elemental

scandium chip is used to adjust the metal/iodine ratio in the lamp and to getter oxygen impurities.

The above chemistry can be modified by the replacement of the element cesium with lithium to form a chemistry of $NaIScI_3LiI$. The resulting lamp has an improved CRI of 73 while still maintaining the 10,000 hour life and the 85 LPW efficacy. However, a CRI of 73 must be further improved for the excellent color rendering needed for showroom lighting, displays in stores, and decorative illumination, both for indoor and outdoor use.

Presently available HID lamps, such as the Osram POWERSTAR$^R$ HQI-TS metal halide lamp, have a high CRI on the order of 85 but have a relatively short lifetime of 6000 hours. These lamps have a correlated color temperature (CCT) of 4300 K and LPW of 73 to 80. The POWERSTAR$^R$ lamps depend on a rare earth chemistry, $HoI_3$, $TmI_3$, and $DyI_3$ plus NaI. These lamps generally have a lower LPW than $NaI-ScI_3$ types and a pronounced decline of LPW with operating time. Lamps of this type are generally designed with a higher wall temperature for the arc tube in order that sufficient concentration of the rare earth elements will be present in the arc discharge. The attendant disadvantage of these lamps is their shortened life, which is a consequence of the elevated operating temperature.

As set forth in U.S. patent 4,866,342 to Ramaiah, the sodium scandium lamp has achieved popularity due to its very good luminous efficacy and long operating life. The patent describes a metal halide lamp having a discharge sustaining fill within an arc tube consisting essentially of a rare gas,

mercury, and the halides of sodium and scandium, characterized in that the fill additionally contains thallium halide in the mole ratio of sodium halide to thallium halide of about 280:1 to 75:1 whereby the luminous efficacy of the lamp is increased without substantially adversely affecting the color rendering index of the lamp. As set forth in column 2, lines 51 to 56, an improvement in the luminous efficacy and the color rendering index occurs within the narrow range of 260:1 to 240:1 mole ratio of sodium halide to thallium halide. As set forth in the example in column 4, the highest reported color rendering index was 62 for Lot B. This patent is illustrative of the sensitivity of HID lamps to various dopants and the unpredictability of lamp performance depending on the various ingredients present in the fill. It is desirable to make further enhancements in luminous efficacy and color rendering index while achieving or maintaining a long lamp life.

U.S. patent 4,053,805 to Scholz et al relates to a red emitting metal halide arc discharge lamp utilizing a fill of mercury, scandium and lithium iodide. Lithium iodide imparts a red component to the emitted light. Problems encountered with lithium iodide as a lamp fill component, as set forth in the above patent, include lamp starting problems and electrode attack. These problems were reduced by the addition of scandium metal to the fill.

U.S. patent 4,709,184 to Keeffe et al relates to a metal halide lamp where the fill consists essentially of sodium iodide and scandium iodide in a molar ratio in the range of about 20:1 to 28:1, elemental mercury, scandium, and an inert gas. U.S. patent 4,963,790 of White et al describes a floating frame structure for reducing the sodium electrolysis process.

U.S. patent 5,057,743 to Keeffe and Krasko relates to a metal halide lamp having a chemical fill including sodium iodide, lithium iodide, and scandium iodide. Although lamps exhibit long life, high luminous efficacy, and good color temperature, a futher improvement in the color rendering index would be desirable.

U.S. patent 3,979,624 to Liu et al describes, in column 5, lines 54 to 60, a lamp with a ratio of sodium halide to scandium halide at 11.5:1 with a color rendering index of 56 and a lamp with a ratio of 2.5:1 with a CRI at 69. Column 7, lines 17 to 24, discloses "small amounts" of a rare earth can "be used to supplement the charge-sustaining fill." They teach that rare earth is added in "small amounts," and teach that "small amounts" are 2 mg or less for a 20 mg total fill weight. No improvement in lamp performance or color rendering index is reported for such small additions of rare earth.

Because of their superior efficacy and operating life, lamps utilizing a chemical fill of $NaIScI_3LiI$ with a scandium metal getter are highly desirable. However, due to their color rendering properties, their commercial use in certain color-critical applications has been limited.

## SUMMARY OF THE INVENTION

It is an object of the present invention to increase the color rendering index for an HID lamp utilizing the $NaIScI_3LiI$ chemistry while maintaining the efficacy and long life characteristic of such lamps.

It is another object of the present invention to increase

the density of the rare earth atoms in the arc without necessitating a detrimental increase in the cold spot temperature.

It is another object of the present invention to improve the color rendering properties of the lamp while maintaining a long lamp life.

It is another object of the present invention to increase the density of the rare earth species above the density obtainable with a rare earth iodide alone.

It is another object of the present invention to increase the density of the rare earth atoms in the arc by forming a complex molecule containing the rare earth element.

It is another object of the present invention to have a wall temperature of the arc tube that is conducive to a long lamp life.

Other objects and advantages of the present invention are apparent from reading the specification and claims.

The present invention provides a discharge lamp having an enhanced color rendering index because of an improved emission spectrum during operation. Structurally, the lamp includes a glass envelope with an arc tube disposed therein. A pair of electrical conductors extending into the interior of the glass envelope are electrically connected to a pair of electrodes in the arc tube for creating an electric discharge during lamp operation. A chemical fill for within the arc tube comprises an inert starting gas, mercury, alkali metal iodides, scandium

iodide, and at least one iodide of a rare earth. The alkali metal iodides comprises sodium iodide and lithium iodide. The iodide of a rare earth and scandium iodide are present in amounts sufficient to form a complex for increasing the density of the rare earth in the discharge gas during lamp operation to effect a color rendering index greater than about 80 and a color temperature between about 3000 to about 5000 Kelvin. Due to the increased density of the rare earth in the discharge gas at lower temperatures of operation, the wall temperature of the arc tube is desirably maintained at a temperature between about 800 to 1000 degrees Celsius so that the resulting lamp has a lifetime in excess of 10,000 hours.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a cross-sectional view of a metal iodide discharge lamp.

FIG. 2 shows the optical spectrum of a prior art $NaIScI_3LiI$ lamp, i.e., a lamp not containing a rare earth in accordance with the present invention.

FIG. 3 shows the optical spectrum of a $NaIScI_3LiITmI_3$ lamp typical of the present invention.

FIG. 4 shows efficacy versus time for 3000 hours of operation of a $NaIScI_3LiITmI_3$ lamp typical of the present invention.

A detailed description of this invention is given below. This description uses the four Figures cited here. Other and

further advantages of this invention will become apparent to those skilled in the art through this description.

## DETAILED DESCRIPTION

Referring to FIGURE 1, there is shown the structural features of a metal iodide discharge lamp. The illustrated lamp includes a fused quartz discharge tube or arc tube 1 disposed within an outer sealed glass envelope 11. A pair of electrical conductors 18 and 19, which are sealed into and pass through the stem member 14, are connected to external base member 10 for the flow electrical current from an external source (not shown) for energization of the discharge lamp.

The arc tube 1 has a pair of spaced apart electrodes 2 and 3 which project into the interior of the arc tube 1 at respective ends. Each electrode 2 and 3 comprises a tungsten rod surrounded by tungsten wire coils. The electrodes 2 and 3 are connected to respective metal foils 4 and 5. The metal foils 4 and 5 are formed of molybdenum and are sealed in the ends of the arc tube 1, typically by pinch sealing. The metal foils 4 and 5 are connected to lead-in conductors 6 and 7 which project outwardly away from opposite ends of the arc tube 1 along the longitudinal axis of the arc tube 1. Arc tube 1 is generally made of fused quartz although other types of material, such as alumina (PCA), yttria, or sapphire, may be used. The arc tube for use in a 100 watt size lamp, for example, has an internal diameter of 10 mm and an arc length of 14 mm.

The wall temperature of the arc tube 1 is determined by the design parameters. The wall temperature is dependent on

multiple factors such as the radiation transmission properties, the thermal conductance, diameter, length, and wall thickness of the arc tube. Providing an evacuated outer jacket tends to increase the arc tube temperature at a fixed power loading. In the present invention, the outer envelope 11 is most preferably evacuated with the outer envelope 11 hermetically sealed to the glass stem member 14. The wall temperature of the arc tube in the lamp of the present invention is preferably between about 800 to about 1000 degrees Celsius.

The electrodes 2 and 3 are electrically connected to respective electrical conductors 18 and 19. This electrical connection, which is illustrated in detail in Fig. 1, also provides support for the arc tube 1. Lead-in conductor 7 which extends from the lower end of the arc tube 1 is directly connected to conductor 19. Lead-in conductor 6 which extends from the upper end of the arc tube 1 is indirectly connected to conductor 18 through support conductors 25, 27, and 29. Support conductors 27, 29 extend in the same direction away from the longitudinal axis of the arc tube 1 so that interconnecting support conductor 25 extends exterior to the radiation shield 13. As a result, the arc tube 1 is electrically isolated from radiation shield 13. The lead-in conductors 6,7 and support conductors 25, 27 and 29 are sufficiently rigid so as to provide adequate and independent support for arc tube 1.

The arc tube 1, which is positioned interior to the radiation shield 13, is electrically isolated from the radiation shield 13 and the support structure 12. Such a "floating frame" structure is used to control the loss of alkali metal from the arc tube fill by electrically isolating

the support structure. Such a structure is described in U.S. patent 5,056,743 to Krasko et al and in U.S. patent 4,963,790 of White et al which specification is incorporated by reference into the present specification. In particular, the radiation shield 13 is referred to as a heat loss reducing member. The arc tube is disposed within the heat loss reducing member. A support for the heat loss reducing member is electrically isolated from the electrical conductors and the electrodes.

Within the outer envelope 11, support member 12, which is electrically insulated from the electrical conductors 18 and 19, holds radiation shield 13. Support member 12, which extends substantially parallel to the longitudinal axis of the lamp, is secured to an insulated portion of glass stem member 14 at one end and to outer envelope 11 at the other end. The envelope attachment 15 is in the form of a circular configuration which mates with a dimpled upper partition of the envelope 11 so as to maintain the support structure 12 electrically isolated and properly aligned. A pair of getters 20 and 21 are shown mounted to the support structure 12.

The radiation shield 13 is secured to the support structure 12 by spaced apart straps 16 and 17 which are welded to a vertically aligned portion of the support member 12. The radiation shield 13 has a cylindrical shape and is typically in the form of a quartz sleeve which can have a domed shaped closure at one end: Each of the straps 16 and 17 is made of a spring-like material so as to hold the shield 13 firmly in position. As set forth in U.S. patent 4,859,899, the diameter and length of the radiation shield may be chosen with respect to the arc tube dimensions to achieve the optimal radiation redistribution resulting in uniform arc tube wall

temperatures.

The lamp may include other structural features commonly found in metal iodide lamps, such as an auxiliary starting device. Although the drawing illustrates a medium screw type base 10. it is contemplated that the lamp may have a double-ended configuration with a recessed single-contact base.

A chemical fill which forms an electrical discharge sustaining gas for emitting radiation is disposed within the arc tube 1. The chemical fill contains a base chemistry of an inert starting gas, mercury, alkali metal iodides, and scandium iodide. The desired base chemistry contributes to the desirable lamp characteristics of low wall temperature, high LPW, moderate CRI, and long life. The lamp emission due to the base chemistry is approximately on the black body chromaticity locus.

In addition to the appropriate base chemistry, the chemical fill comprises at least one iodide of a rare earth element which is at least partially vaporized during lamp operation. The iodide of a rare earth and scandium iodide are present in a molar ratio sufficient to form a complex for increasing the concentration of the rare earth in the discharge gases during lamp operation at a low arc tube wall temperature. Due to the formation of the complex, the vapor phase concentration of the rare earth is increased at the arc tube wall temperature beyond what is obtainable using the rare earth iodide alone. The wall temperature of the arc tube in the lamp of the present invention is preferably maintained between about 800 to about 1000 degrees Celsius.

In accordance with the principles of the present invention, the improved chemical fill comprising the base chemistry and at least one rare earth iodide enhances the color rendering index of the lamp. Due to the presence of the rare earth atoms in the discharge gas, the lamp has a color rendering index greater than about 80. Preferably, the color rendering index is greater than 85 and more preferably greater than 90.

High color rendering indices, on the order of about 90, are easier to realize at high correlated color temperatures (CCT). In a preferred embodiment, the present invention achieves high $R_a$ at relatively low CCT between 3000 and 4000 Kelvin.

During lamp operation, the amount of rare earth in the arc is sufficient to produce an enhanced color rendering index while maintaining the relatively low arc tube wall temperature that is conducive to long lamp life. The formation of complex molecules of the rare earth with scandium iodide results in an increased density of rare earth atoms in the arc.

In the present invention, rare earth is present in an amount sufficient to complex with scandium iodide in order to increase the density of the rare earth atoms in the vapor during lamp operation to the desired level. Preferably the molar ratio of the rare earth iodide to scandium iodide in the fill is between about 1:1 to about 30:1, and more preferably between about 5:1 to about 20:1. A most preferred molar ratio is about 15:1.

Due to their many emission lines, all rare earths may enhance the arc performance of a lamp, at least to some degree

and in some respect. The rare earths are selected from the group consisting of La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu and mixtures thereof. The choice of rare earth depends on the desired radiation characteristics. The preferred rare earths for enhanced CRI are the iodides of cerium, praseodymium, neodymium, dysprosium, holmium, erbium, thulium, and lutetium. According to one embodiment the rare earth iodide is present as a single rare earth iodide selected from the above preferred group. Even more preferred are the rare earth iodides of cerium, praseodymium, dysprosium, holmium, and thulium.

A charge of mercury is present in a sufficient amount so as to establish the electrical characteristics of the lamp by desirably increasing the electric field strength to sustain a desirable power loading. Such an amount should provide an operating mercury pressure between 1 to about 100 atmospheres, and preferably between about 1 to about 20 atmospheres.

In addition to mercury, a small charge of an inert ionizable starting gas such as argon is contained within the arc tube 1. It is contemplated that other noble gases can be substituted for argon provided an appropriate pressure is maintained that is conducive to starting the lamp.

To achieve the above discussed desirable lamp properties, the scandium iodide and the alkali metal iodides are present in the fill and in the discharge gas during lamp operation. These ingredients form a base chemistry which is conducive to the low arc tube wall temperature and long lamp life. These ingredients also improve color quality by adding a variety of lines to the emission spectrum and are preferably present in

amounts for producing emission with its color substantially on the black body radiator chromaticity locus. The molar ratio of sodium iodide to scandium iodide is between about 5:1 to about 25:1. The ratio of sodium iodide to lithium iodide is between about 1:1 to about 5:1.

The alkali metal iodides adjust the current-voltage characteristics, stabilize the arc by reducing arc constriction, improve the color quality, and contribute to lumen output of the lamp through strong emissions. In the present invention, the "efficacy" in lumens per watt (LPW) is preferably greater than about 75, and more preferably greater than about 80.

The addition of a rare earth iodide, according to the preferred embodiments, substantially maintains the LPW near or above 80 while improving the CRI from about 73 to above 80, and while preserving the CCT between 3000 and 5000 Kelvin.

In the present invention, the selection of fill ingredients results in a desirable color temperature between 3000 K and 5000 K, more preferably between about 3000 to about 4000 Kelvin. The molar ratios of the ingredients are selected also so that the resulting emission color is near the highly desirable black body (BB) chromaticity locus at this desired color temperature.

In addition to the above-mentioned fill ingredients, scandium, thorium, cadmium, or zinc may be added to the fill as metals or alloys to adjust the metal/iodine ratio in the lamp and to getter oxygen impurities. The preferred additive is scandium. For a low wattage metal iodide discharge lamp with a

lamp wattage less than 175 watts, e.g., between 40 to 150 watts, the scandium metal weight dosage is preferably about 100 micrograms per cubic centimeter of arc tube volume at all wattages. The total fill weight varies with lamp operating power between about 4 and about 20mg. For example, the 100 watt lamp fill is preferably between about 4mg and about 8 mg, and more preferably between about 5.5 and about 6.5 mg.

## AN EMBODIMENT OF THE INVENTION

For 40-150 watt lamps, the arc tube has a volume of 0.3-2.2 $cm^3$, respectively. The chemical fill has a base chemistry of about 13 to 8 $mg/cm^3$ mercury, respectively, and about 90 to about 150 torr starting gas; about 0.1 to about 0.5 $mg/cm^3$ scandium iodide; about 1 to about 3 $mg/cm^3$ sodium iodide; about 0.3 to about 0.5 $mg/cm^3$ lithium iodide; about 0.1 to about 0.2 $mg/cm^3$ scandium metal. For the particular rare earth additive, thulium iodide, about 2.5 to about 4 $mg/cm^3$ thulium iodide is included. Preferably the tube has a wall loading in the range of about 12 to 17 $watts/cm^2$, respectively, for the 40-150 W lamps. The total amount of fill is between about 4 mg to about 20 mg. Those skilled in the art will recognize that all chemicals introduced into the lamp fill are desirably of the highest purity attainable. Also, it should be recognized that the iodide compound may be synthesized in situ by introducing the constituents in other forms. For example, instead of introducing a rare earth iodide, the rare earth iodide may be synthesized within the arc tube by using, as the lamp fill components, the rare earth metal plus mercury iodide rather than the rare earth iodide plus mercury metal.

## EXAMPLES

The following examples are provided to enable those skilled in the art to understand more clearly and practice the present invention. These examples should not be construed as a limitation upon the scope of the present invention but merely as being illustrative and representative thereof.

Two sets of 100-watt metal iodide lamps were made to compare lamps of the present invention with lamps not including scandium iodide in order to demonstrate that scandium iodide acts as a complexing agent component for the rare earth iodide. This first example utilizes thulium iodide. Each of the lamps included a quartz arc tube having an internal volume of about 1.25 $cm^3$, an arc gap of about 14 mm, an electrode insertion length of about 2.5 mm, and an inside diameter of 10 mm. The fill of the arc tube of the first set is set forth in Table 1. The fill components are set forth in weight and in micromoles. The second set of lamps contained the same fill as the first set except for the scandium component. In the second set, no scandium was included. The lamps were operated vertically with their bases up on a standard M90 Advance 100 W ballast. The aging cycle was 10 hours on and 2 hours off.

TABLE I

FIRST SET OF LAMPS

| ACTIVE CHEMICAL FILL | | | | | | GETTER METAL |
|---|---|---|---|---|---|---|
| Hg (mg) | NaI (mg) | $ScI_3$ (mg) | LiI (mg) | Ar (torr) | ReI (mg) | Sc (mg) |
| 13.50 | 1.53 | 0.18 | 0.54 | 100 | 3.75 | 0.13 |
| Hg | Na | Sc | Li | I | ReI | Sc |
| micromoles | | | | | | |
| 67.3 | 10.2 | 0.42 | 4.03 | 36.0 | 6.82 | 2.89 |

Substantial rare earth emission was observed in the first set of lamps. Fig. 3 shows the observed emission spectrum between 380 and 800 nm. Indeed the continuum level is truly non-zero, i.e. Fig. 3 shows unresolved or broadened Tm emissions of significant output power as an underlying continuum. In this graph and in Fig. 2, the zero level is a true zero and the continuum level in Fig. 3 is at least twice that in Fig. 2. A spectroscopic abundance determination based on these and other spectra of thulium indicates that the thulium concentration in lamps with the scandium is two orders of magnitude greater than what is expected based solely on the vapor pressure of the non-complexed thulium iodide at the wall temperature. With the scandium free lamp fill, for the same power dissipation, the Tm emissions were weaker by a factor of about 50.

While there has been shown and described what at present is considered the preferred embodiment of this invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A discharge lamp having an enhanced color rendering index and emission spectrum during operation comprising:

an outer glass envelope and a pair of electrical conductors extending into the interior of said glass envelope;

a discharge tube disposed within the outer glass envelope, said discharge tube being adapted for operation at an discharge tube wall temperature between about 800 to about 1000 degrees Celsius and including a pair of spaced electrodes being electrically connected to said electrical conductors for creating an electric discharge during operation of said lamp;

a chemical fill for forming an electric discharge within the discharge tube during lamp operation, said fill comprising an inert starting gas, mercury, alkali metal iodides consisting essentially of sodium iodide and lithium iodide, scandium iodide, and at least one iodide of a rare earth; and

said iodide of a rare earth and said scandium iodide being present in a molar ratio for increasing the concentration of said rare earth in the discharge so that lamp emission has its color temperature between 3000 Kelvin and 5000 Kelvin and its color rendering index greater than about 80.

2. A discharge lamp in accordance with Claim 1 wherein the molar ratio of said iodide of a rare earth to scandium iodide is between about 1:1 to about 30:1.

3. A discharge lamp in accordance with Claim 2 wherein said discharge tube has a total amount of fill between about 4 mg to about 20 mg.

4. A discharge lamp in accordance with Claim 2 including a heat loss reducing member, said discharge tube being disposed within said heat loss reducing member, a support for said heat loss reducing member being electrically isolated from said said electrical conductors and said electrodes.

5. A discharge lamp in accordance with Claim 2 wherein said iodide of a rare earth iodide is selected from the group consisting of the iodides of cerium, praseodymium, neodymium, dysprosium, holmium, erbium, thulium, lutetium and mixtures thereof.

6. A discharge lamp in accordance with Claim 5 wherein the molar ratio of said sodium iodide to said scandium iodide is between about 5:1 to about 25:1.

7. A discharge lamp in accordance with Claim 6 wherein the molar ratio of said sodium iodide to said lithium iodide is between about 1:1 to about 5:1.

8. A discharge lamp in accordance with Claim 7 wherein said iodide of a rare earth is selected from the group consisting of the iodides of cerium, praseodymium, dysprosium, holmium, thulium or mixtures thereof.

9. A discharge lamp in accordance with Claim 1 wherein said iodide of a rare earth is a single rare earth iodide selected from the group consisting of the iodides of cerium, praseodymium, neodymium, dysprosium, holmium, erbium, thulium, and lutetium.

10. A discharge lamp in accordance with Claim 9 wherein the molar ratio of said iodide of a rare earth to scandium iodide is between about 1:1 to about 30:1.

11. A discharge lamp in accordance with Claim 10 wherein the molar ratio of said sodium iodide to said scandium iodide is between about 5:1 to about 25:1.

12. A discharge lamp in accordance with Claim 11 wherein the molar ratio of said sodium iodide to said lithium iodide is between about 1:1 to about 5:1.

13. A discharge lamp in accordance with Claim 12 wherein said iodide of a rare earth is an iodide of cerium, praseodymium, dysprosium, holmium, or thulium.

14. A discharge lamp in accordance with Claim 12 wherein said discharge tube has a total amount of fill between about 4 mg to about 20 mg.

15. A discharge lamp in accordance with Claim 12 including a heat loss reducing member, said discharge tube being disposed within said heat loss reducing member, a support for said heat loss reducing member being electrically isolated from said said electrical conductors and and said electrodes.

16. A discharge lamp in accordance with Claim 1 wherein said scandium iodide and said alkali metal iodides are present in amounts for producing emission with its color substantially on the black body radiator chromaticity locus.

17. A discharge lamp in accordance with Claim 16 wherein

said iodide of a rare earth iodide is selected from the group consisting of the iodides of cerium, praseodymium, neodymium, dysprosium, holmium, erbium, thulium, lutetium and mixtures thereof.

18. A discharge lamp in accordance with Claim 17 wherein the molar ratio of said sodium iodide to said scandium iodide is between about 5:1 to about 25:1.

19. A discharge lamp in accordance with Claim 18 wherein the molar ratio of said sodium iodide to said lithium iodide is between about 1:1 to about 5:1.

20. A discharge lamp in accordance with Claim 19 wherein said iodide of a rare earth is selected from the group consisting of the iodides of cerium, praseodymium, dysprosium, holmium, or thulium.

21. A discharge lamp in accordance with Claim 16 wherein said iodide of a rare earth is a single rare earth iodide selected from the group consisting of the iodides of cerium, praseodymium, neodymium, dysprosium, holmium, erbium, thulium, and lutetium.

22. A discharge lamp in accordance with Claim 21 wherein the molar ratio of said iodide of a rare earth to scandium iodide is between about 1:1 to about 30:1.

23. A discharge lamp in accordance with Claim 22 wherein the molar ratio of said sodium iodide to said scandium iodide is between about 5:1 to about 25:1.

24. A discharge lamp in accordance with Claim 23 wherein the molar ratio of said sodium iodide to said lithium iodide is between about 1:1 to about 5:1.

25. A discharge lamp in accordance with Claim 24 wherein said iodide of a rare earth is an iodide of cerium, praseodymium, dysprosium, holmium, or thulium.

26. A discharge lamp in accordance with Claim 16 wherein said discharge tube has a total amount of fill between about 4 mg to about 20 mg.

27. A discharge lamp in accordance with Claim 16 including a heat loss reducing member, said discharge tube being disposed within said heat loss reducing member, a support for said heat loss reducing member being electrically isolated from said said electrical conductors and and said electrodes.

28. A discharge lamp comprising a chemical fill consists essentially of about 13 to 8 $mg/cm^3$ mercury and about 90 to about 150 torr starting gas; about 0.2 to about 0.51 $mg/cm^3$ scandium iodide; about 1 to about 3 $mg/cm^3$ sodium iodide; about 0.3 to about 0.5 $mg/cm^3$ lithium iodide; and about 2.5 to about 4 $mg/cm^3$ thulium iodide.

29. A discharge lamp in accordance with Claim 28 wherein said discharge tube has a wall loading in the range of about 12 to 17 $watts/cm^2$.

30. A discharge lamp in accordance with Claim 28 wherein said discharge tube has a total amount of fill between about 4 mg to about 20 mg.

31. A discharge lamp in accordance with Claim 28 wherein said lamp comprises an an outer sealed glass envelope and a pair of electrical conductors extending into the interior of said glass envelope; an discharge tube disposed within the outer glass envelope, said discharge tube being adapted for operation at an discharge tube wall temperature between about 800 to about 1000 degrees Celsius and including a pair of spaced electrodes being electrically connected to said electrical conductors for creating an electric discharge during operation of said lamp.

32. A discharge lamp in accordance with Claim 31 including a heat loss reducing member, said discharge tube being disposed within said heat loss reducing member, a support for said heat loss reducing member being electrically isolated from said said electrical conductors and and said electrodes.

33. A low wattage metal iodide discharge lamp in accordance with Claim 28 wherein said lamp has a wattage of about 30 to about 150 watts.

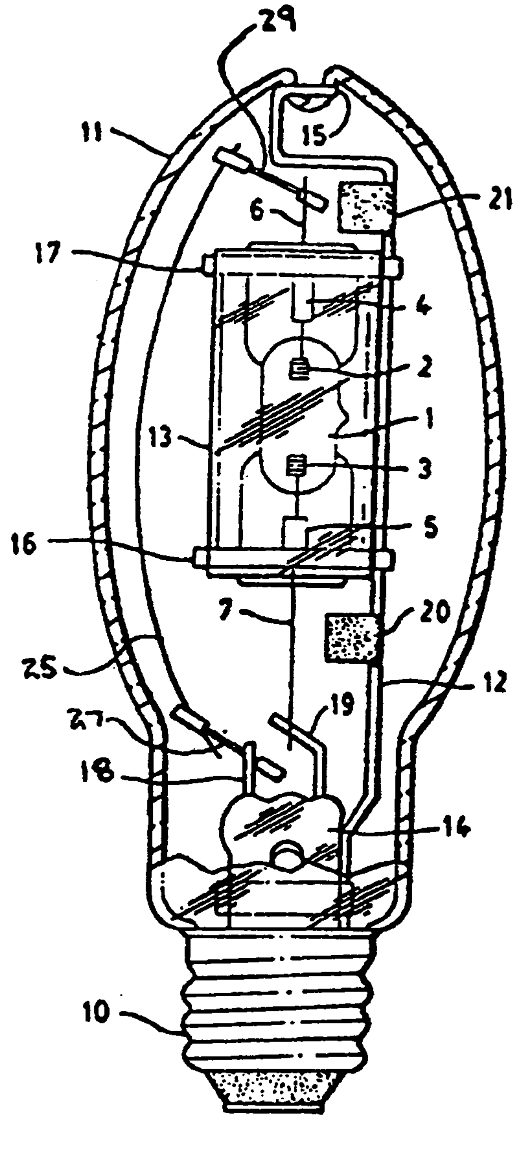



FIG. 1

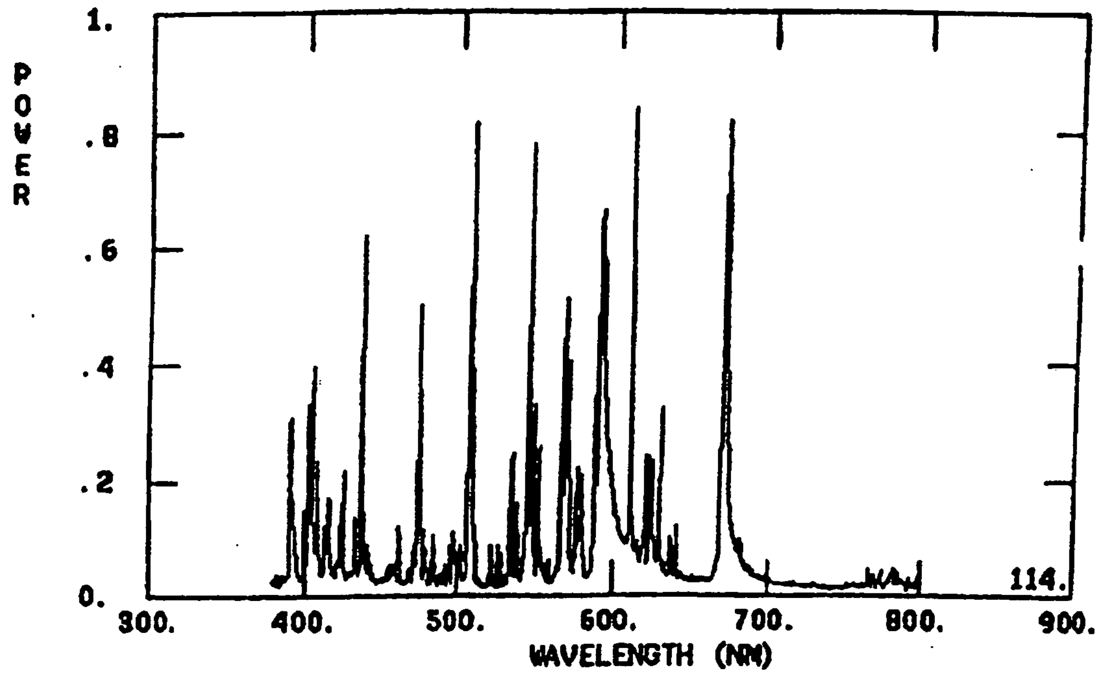



FIG.2

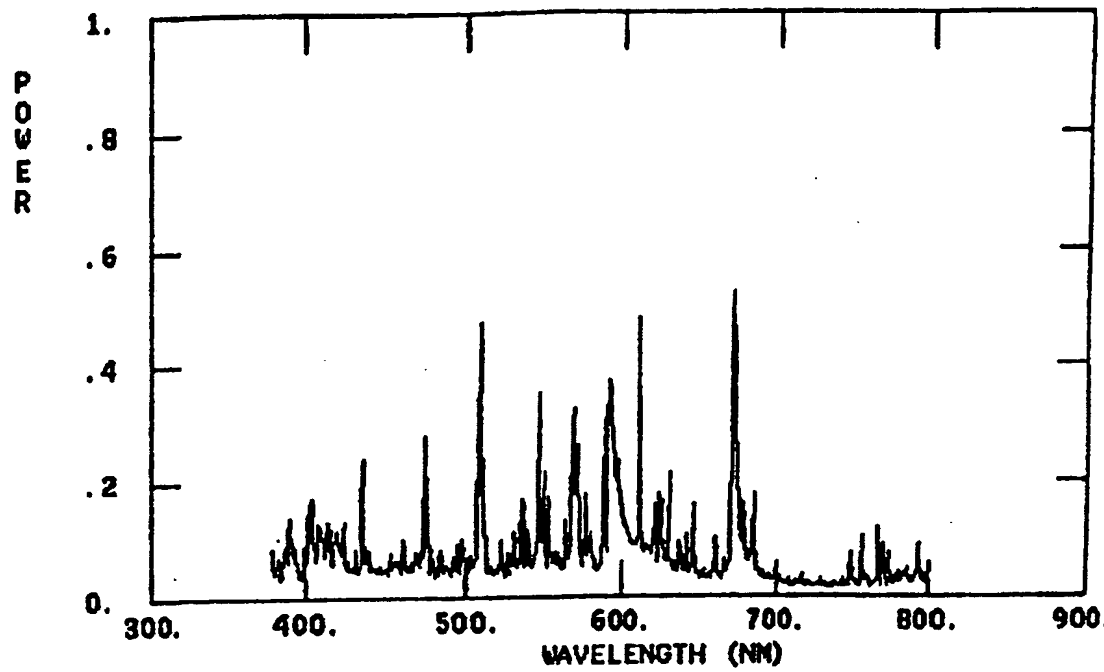



FIG.3

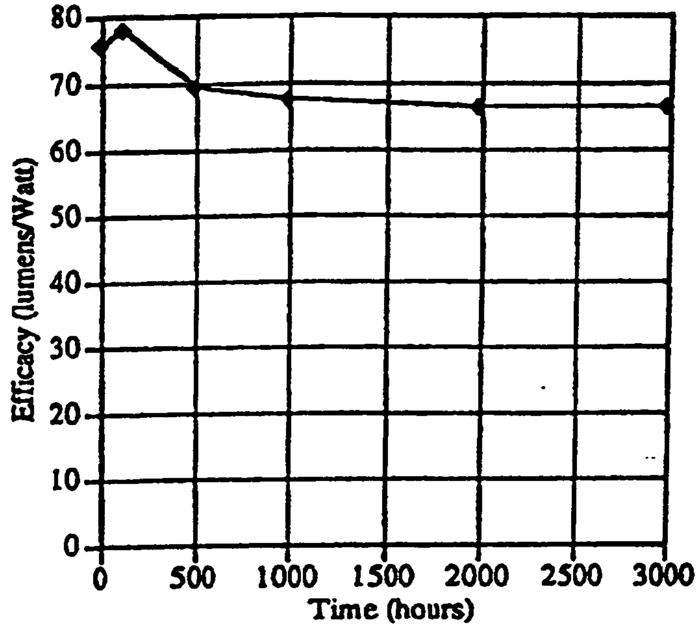

80
70
60
50
40
30
20
10
0
Efficacy (lumens/Watt)
0
500
1000
1500
2000
2500
3000
Time (hours)

Figure 4.

# INTERNATIONAL SEARCH REPORT

International Application No PCT/NL 93/00049

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01J61/12

**II. FIELDS SEARCHED**

Minimum Documentation Searched[7]

| Classification System | Classification Symbols |
|---|---|
| Int.Cl. 5 | H01J |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT**[9]

| Category ° | Citation of Document,[11] with indication, where appropriate, of the relevant passages[12] | Relevant to Claim No.[13] |
|---|---|---|
| A | US,A,3 979 624 (LIU ET AL) 7 September 1976 cited in the application see column 2, line 1 - line 16 see column 5, line 50 - line 60 see column 7, line 4 - line 24 --- | 1,3,5,6, 9,16-18, 21,26 |
| A | EP,A,0 400 980 (IWASAKI ELECTRIC CO. LTD.) 5 December 1990 see column 3, line 16 - line 34 --- | 1 |
| A | EP,A,0 399 288 (GENERAL ELECTRIC COMPANY) 28 November 1990 see claims 1-3 --- | 1 |

-/--

° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 01 JULY 1993 | 09 JUL 1993 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| EUROPEAN PATENT OFFICE | SCHAUB G.G. |

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) | | |
|---|---|---|
| Category ° | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No. |
| A | PATENT ABSTRACTS OF JAPAN vol. 3, no. 126 (M-77)20 October 1979 & JP,A,54 102 070 ( MITSUBISHI DENKI K.K. ) 8 November 1979 see abstract<br>----- | 1 |

# ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

NL 9300049
SA 71614

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 01/07/93

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US-A-3979624 | 07-09-76 | DE-A- 2617915 | 11-11-76 |
| | | FR-A- 2309975 | 26-11-76 |
| | | GB-A- 1537104 | 29-12-78 |
| | | JP-A- 51142882 | 08-12-76 |
| | | NL-A- 7603292 | 02-11-76 |
| EP-A-0400980 | 05-12-90 | JP-A- 3219546 | 26-09-91 |
| EP-A-0399288 | 28-11-90 | US-A- 4983889 | 08-01-91 |
| | | JP-A- 3049147 | 01-03-91 |